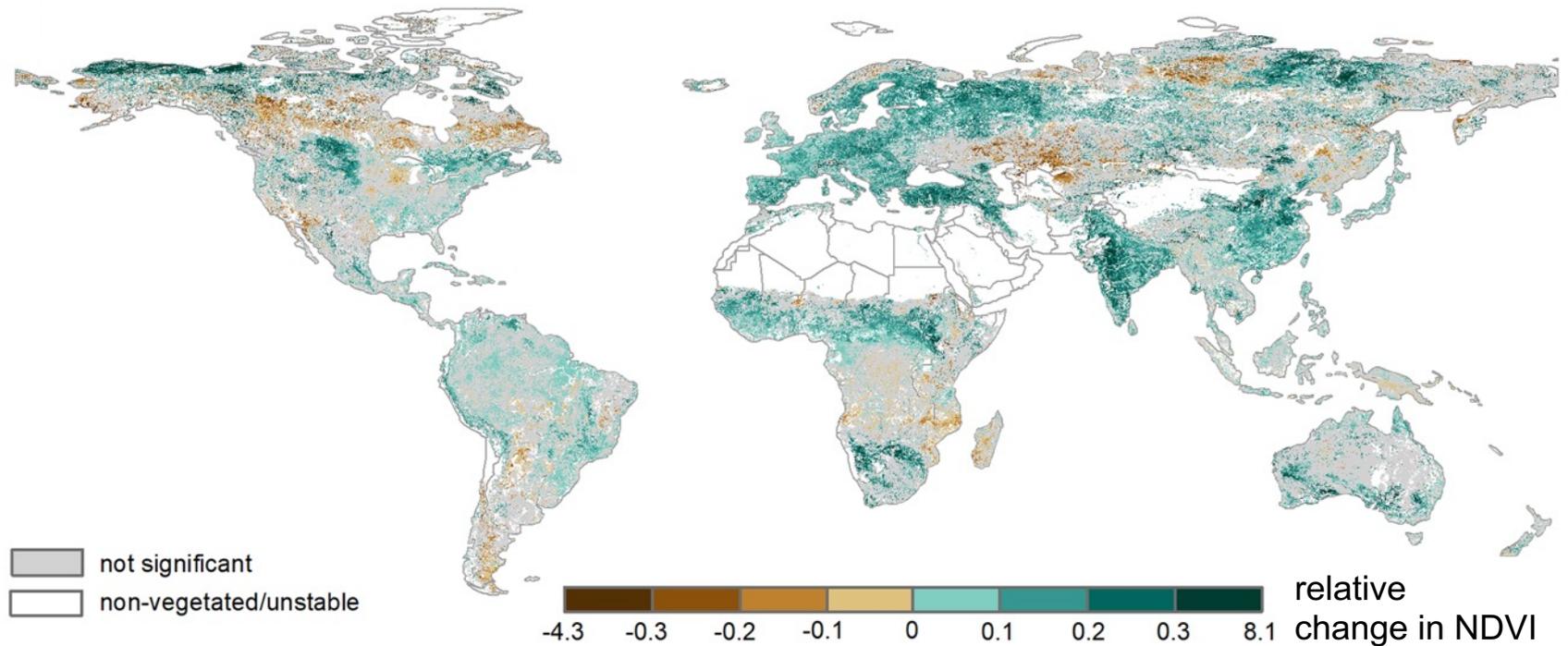


Statistical inference for spatiotemporal trends in remote-sensing data

Anthony R. Ives, University of Wisconsin-Madison



Most ecologists do studies at
fine spatial and temporal scales

Volker C. Radeloff, UW-Madison

Fangfang Wang, Worcester Polytechnic

Jun Zhu, UW-Madison

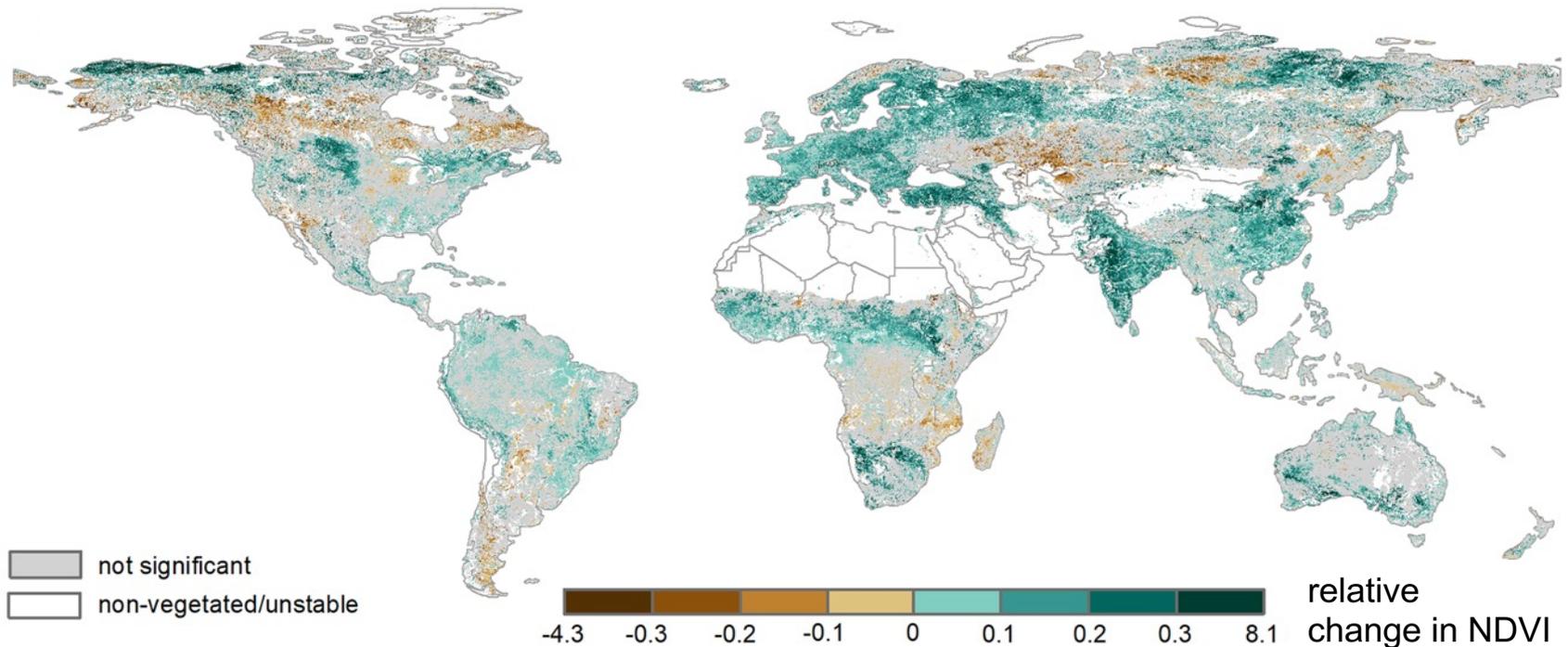


Remote sensing provides a vast amount of data.

Many records start decades ago, giving data to explore historical changes at a global scale.

While the vast amount of the data is one of the greatest strengths of remote-sensing, it is also one of the greatest challenges.

Greening and browning 1982-2015



Outline

1. How is the world greening and browning?
2. Why are patterns hard to statistically find and test?
3. What are the worldwide patterns (as revealed by statistics)?
4. What other types of data can be investigated and tested?

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“Greenness” in remote sensing

NDVI = Normalized Difference Vegetation Index

near infrared image



NDVI



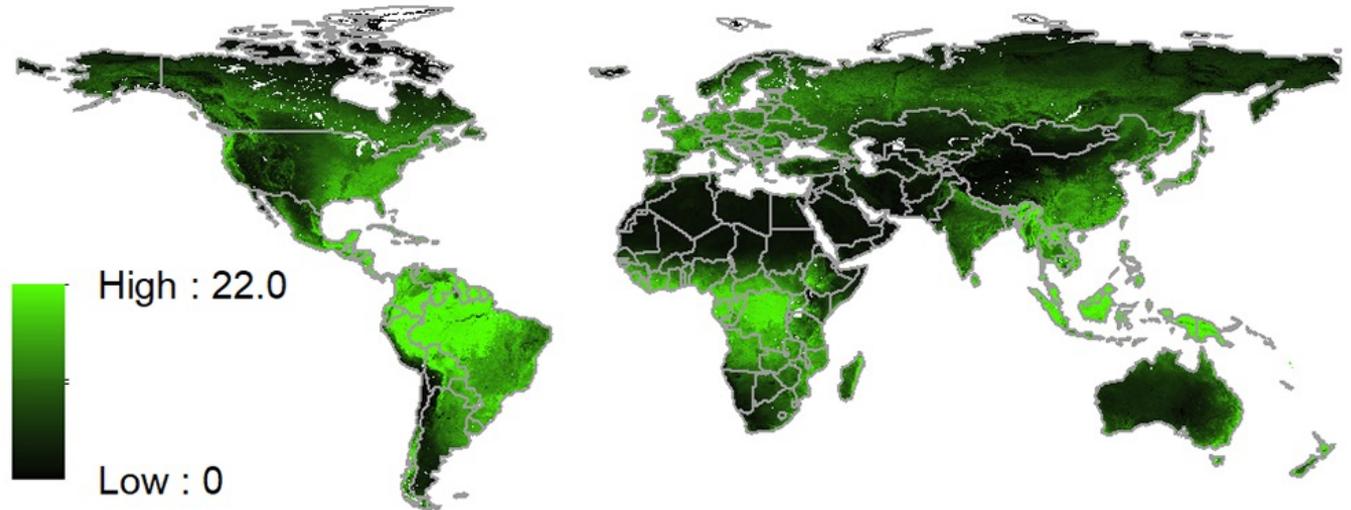
NDVI3g (AVHRR)

Data available at 15-day intervals

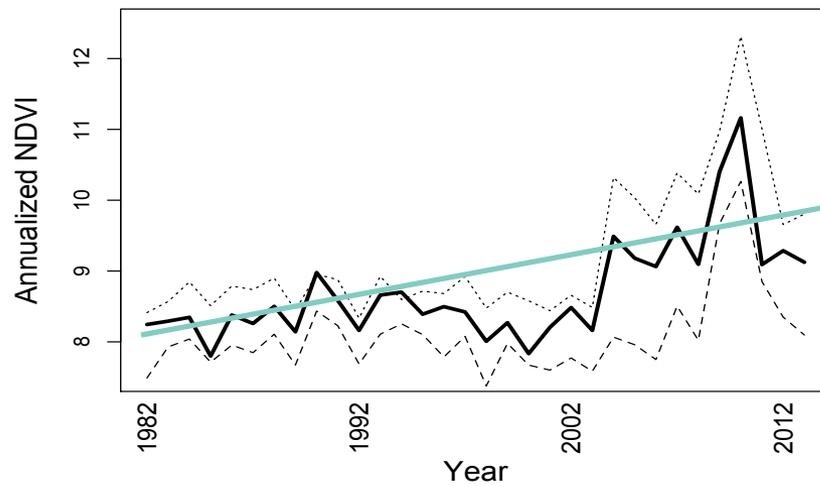
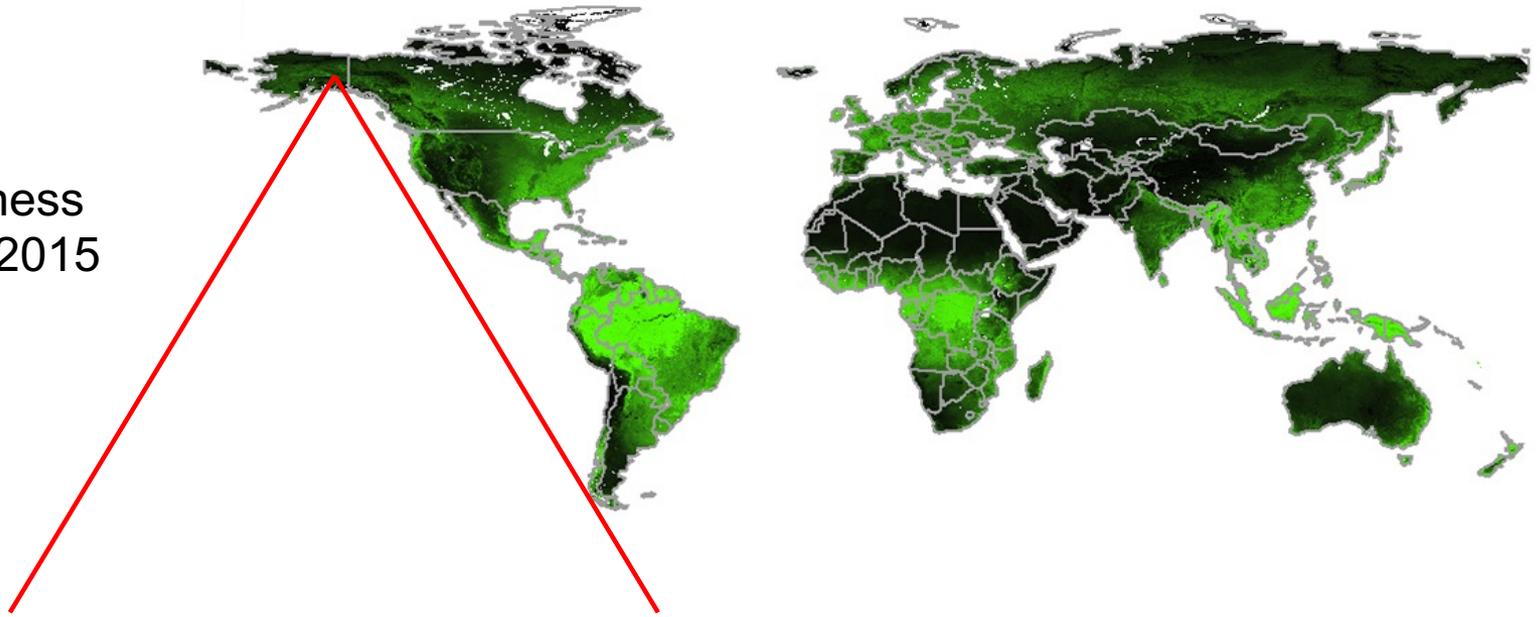
We aggregated the data for each year, 1982-2015

Highly smoothed data give overall patterns

Mean greenness
(NDVI) 1982-2015

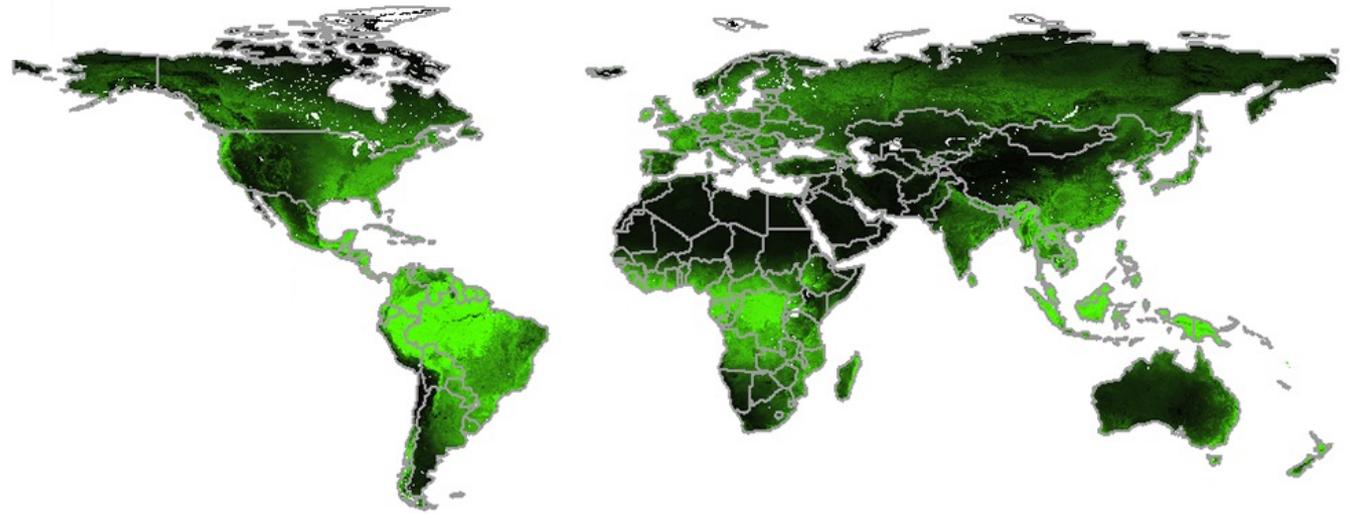


Mean greenness
(NDVI) 1982-2015

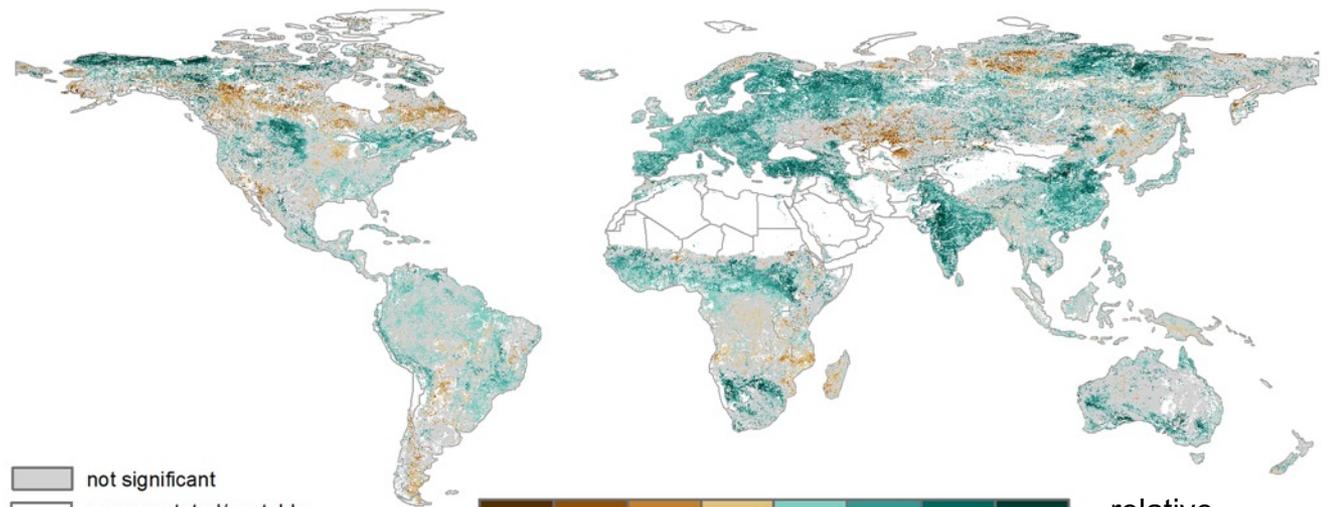


Relative change in NDVI = slope/mean

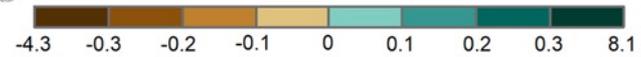
Mean greenness
(NDVI) 1982-2015



Change in
greenness (NDVI)
1982-2015



not significant
non-vegetated/unstable



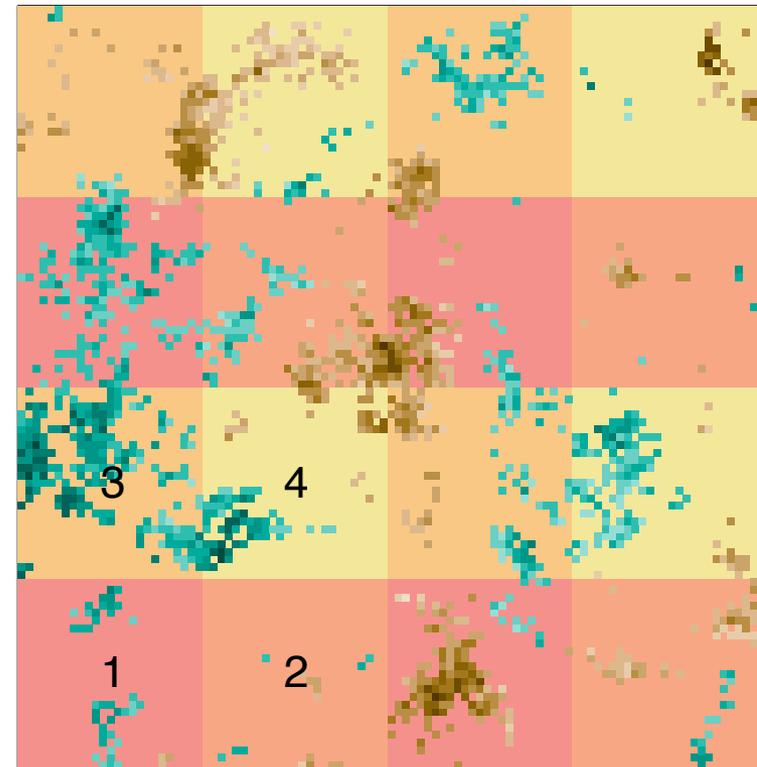
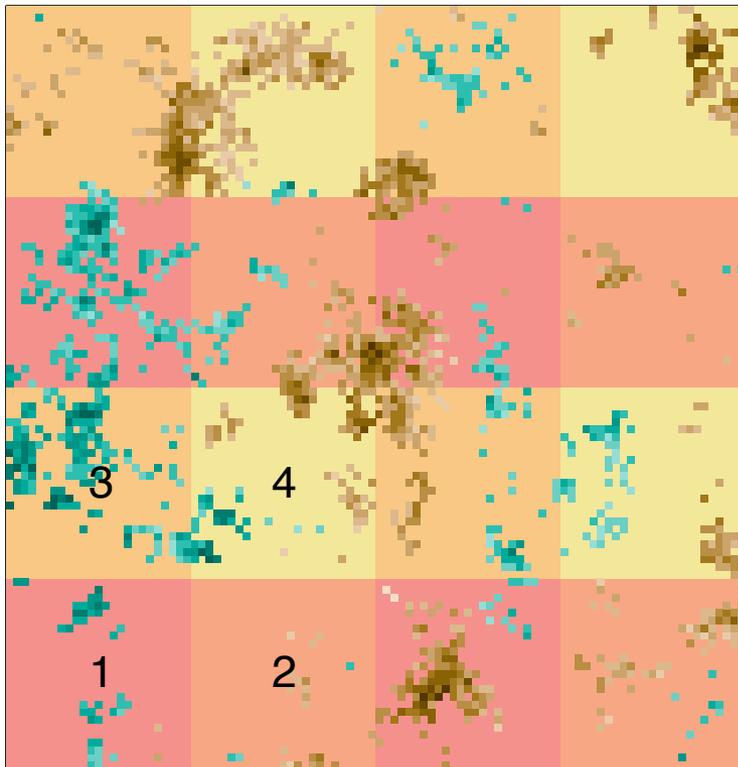
relative
change in NDVI

Outline

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Use computer simulations to create patterns
from known (simulated) processes

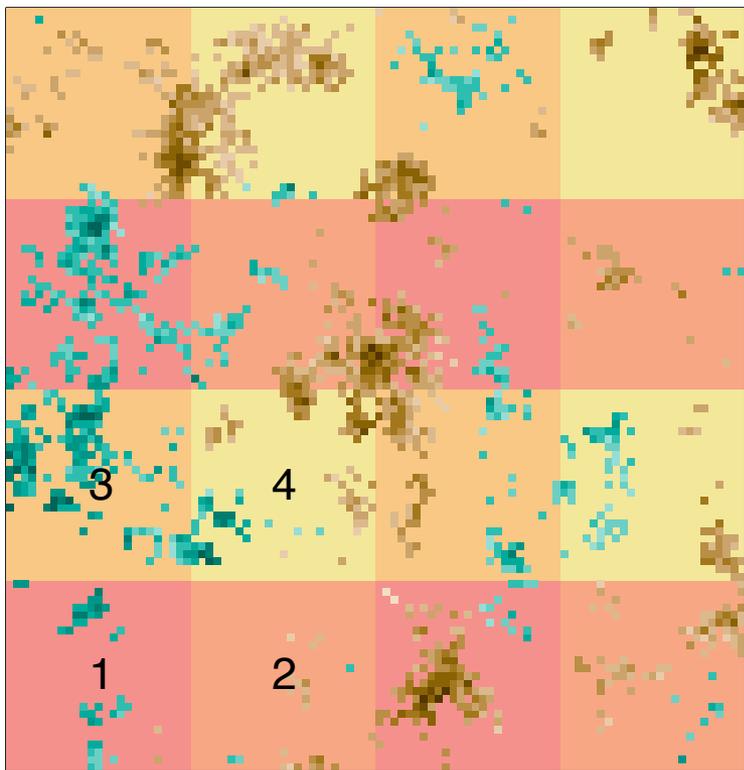
Does greening differ among 4 simulated
land-cover classes?



Same sequence of random numbers used in both simulations

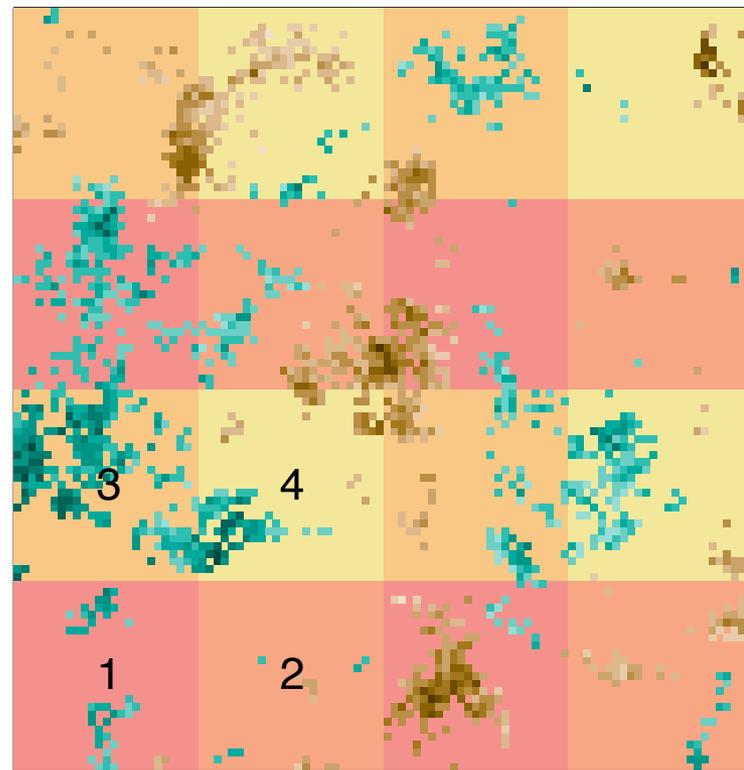
No difference

$$1 = 2 = 3 = 4$$



Difference

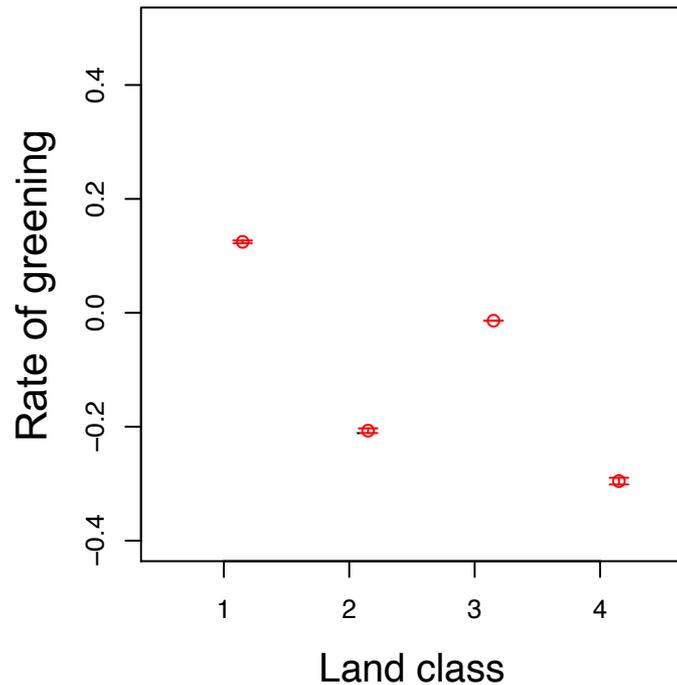
$$1 < 2 < 3 < 4$$



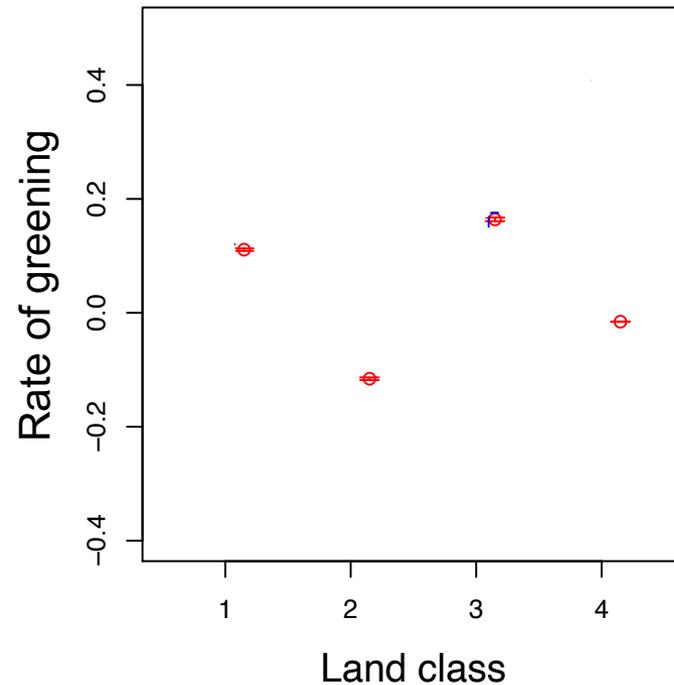
Plots of average time trends per pixel (\pm se)

Not very informative (dangerously misleading)

1 = 2 = 3 = 4



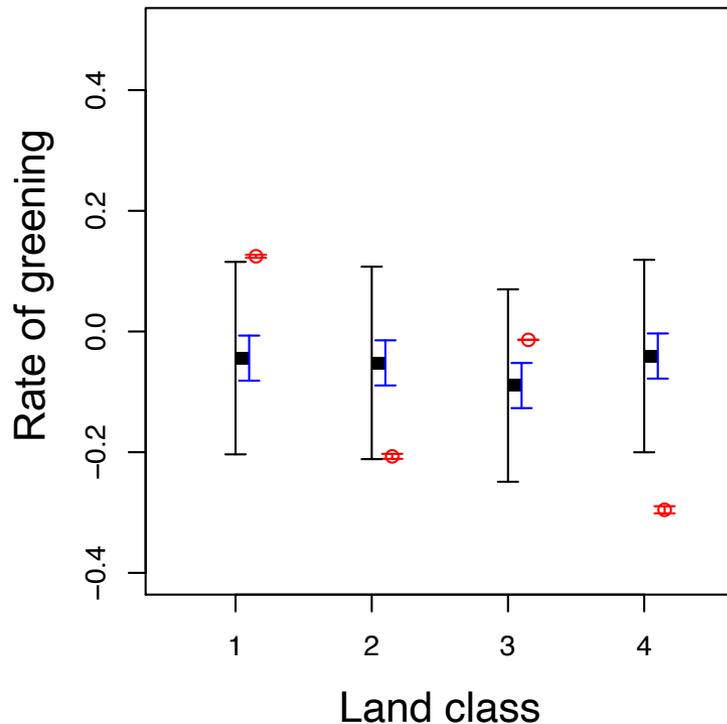
1 < 2 < 3 < 4



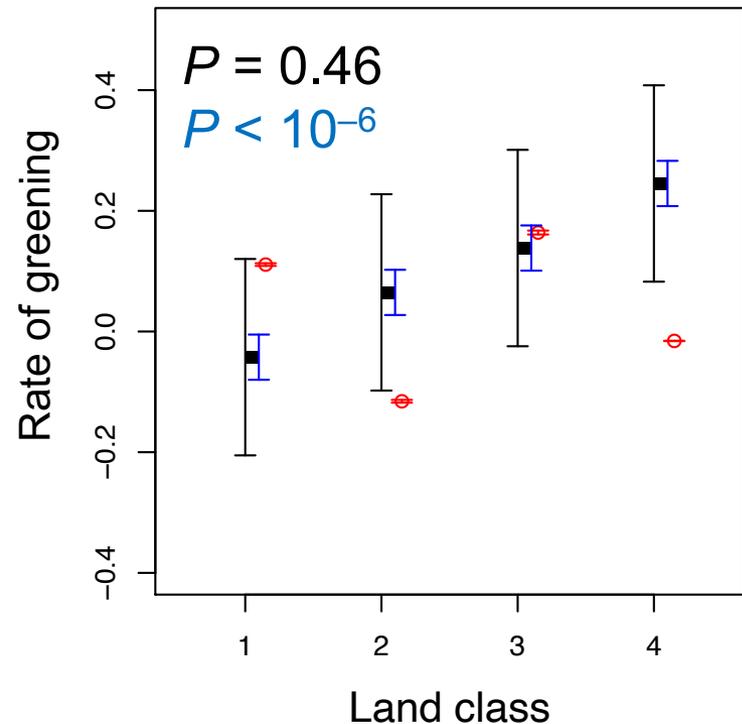
PARTS regression (Partitioned AutoRegressive Time-Series)

Standard errors: differences from zero
 differences from each other

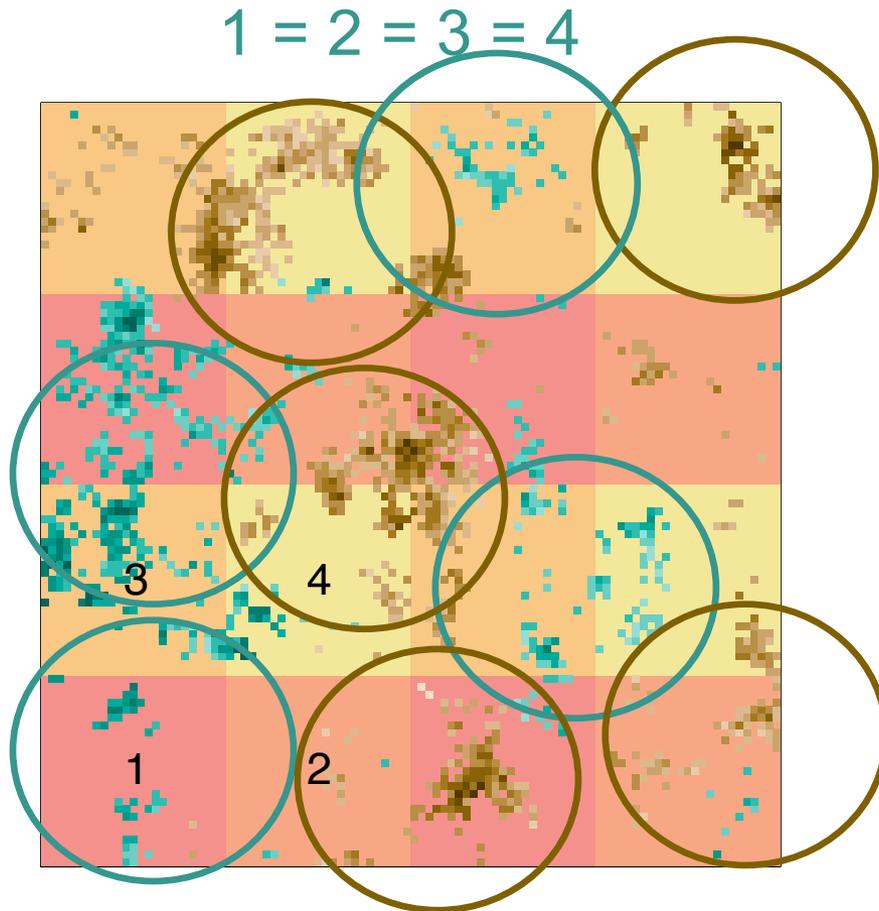
1 = 2 = 3 = 4



1 < 2 < 3 < 4



Why is it easier to detect differences among land-cover classes than differences from zero?



Differences from zero

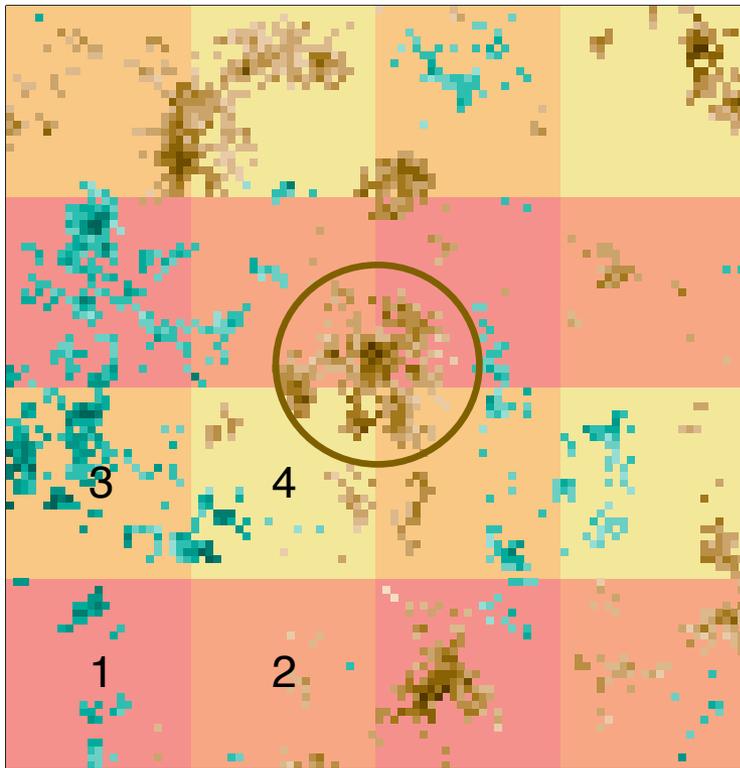
Spatial autocorrelation –
nearby pixels show
similar patterns

Effectively only about 9
independent data points

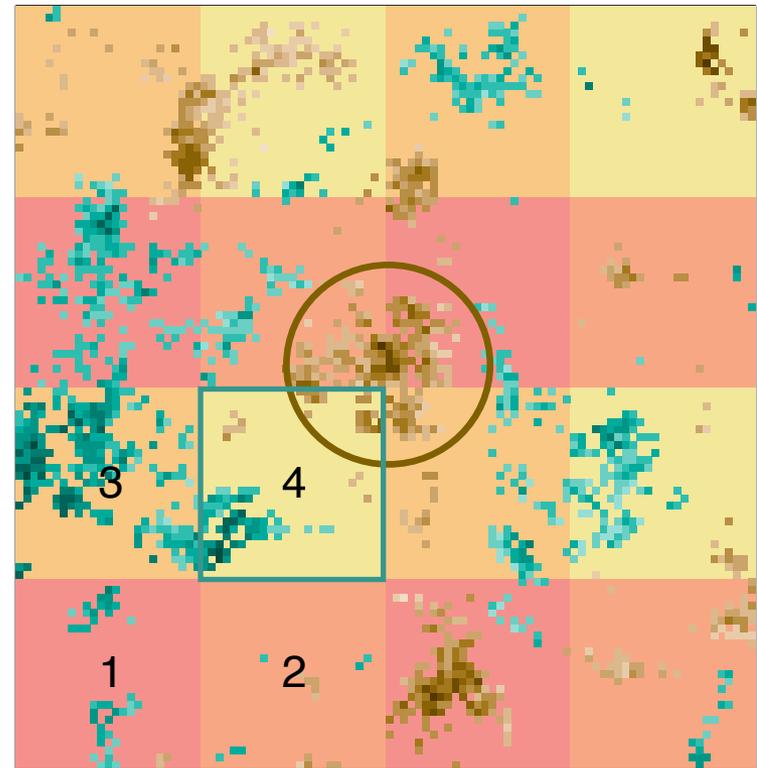
Differences among land-cover classes

Leverage information from nearby pixels

$$1 = 2 = 3 = 4$$



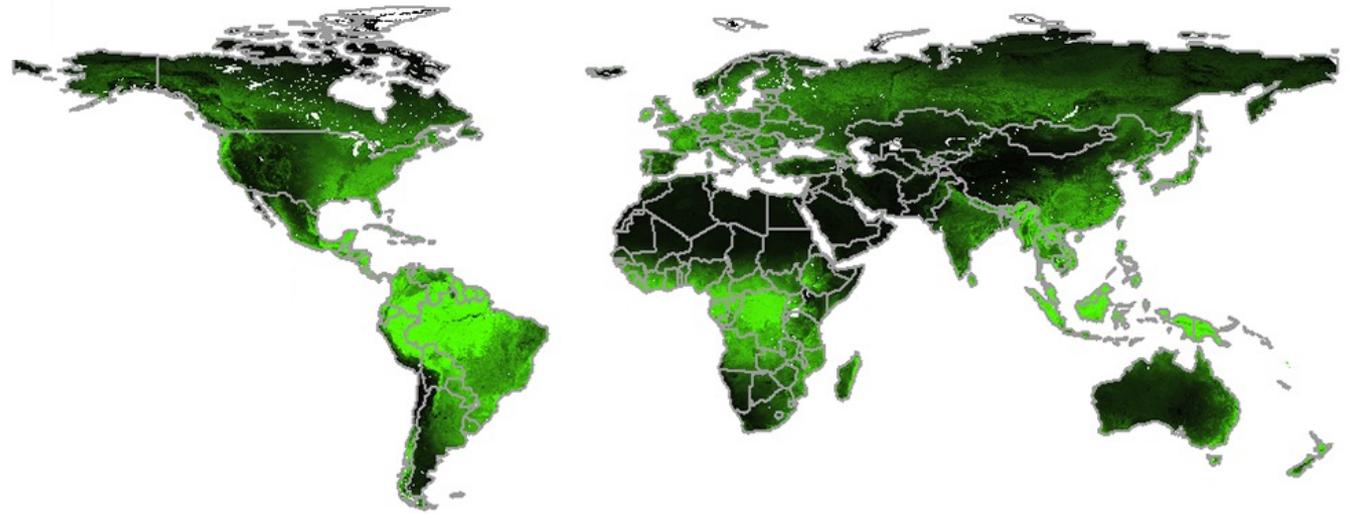
$$1 < 2 < 3 < 4$$



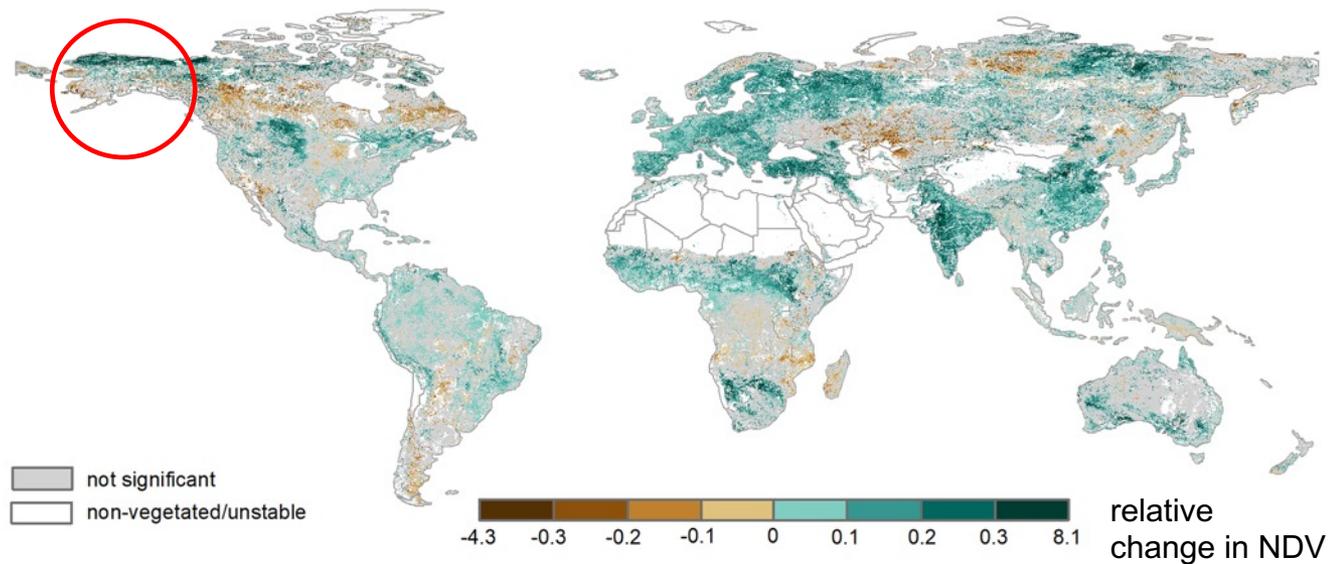
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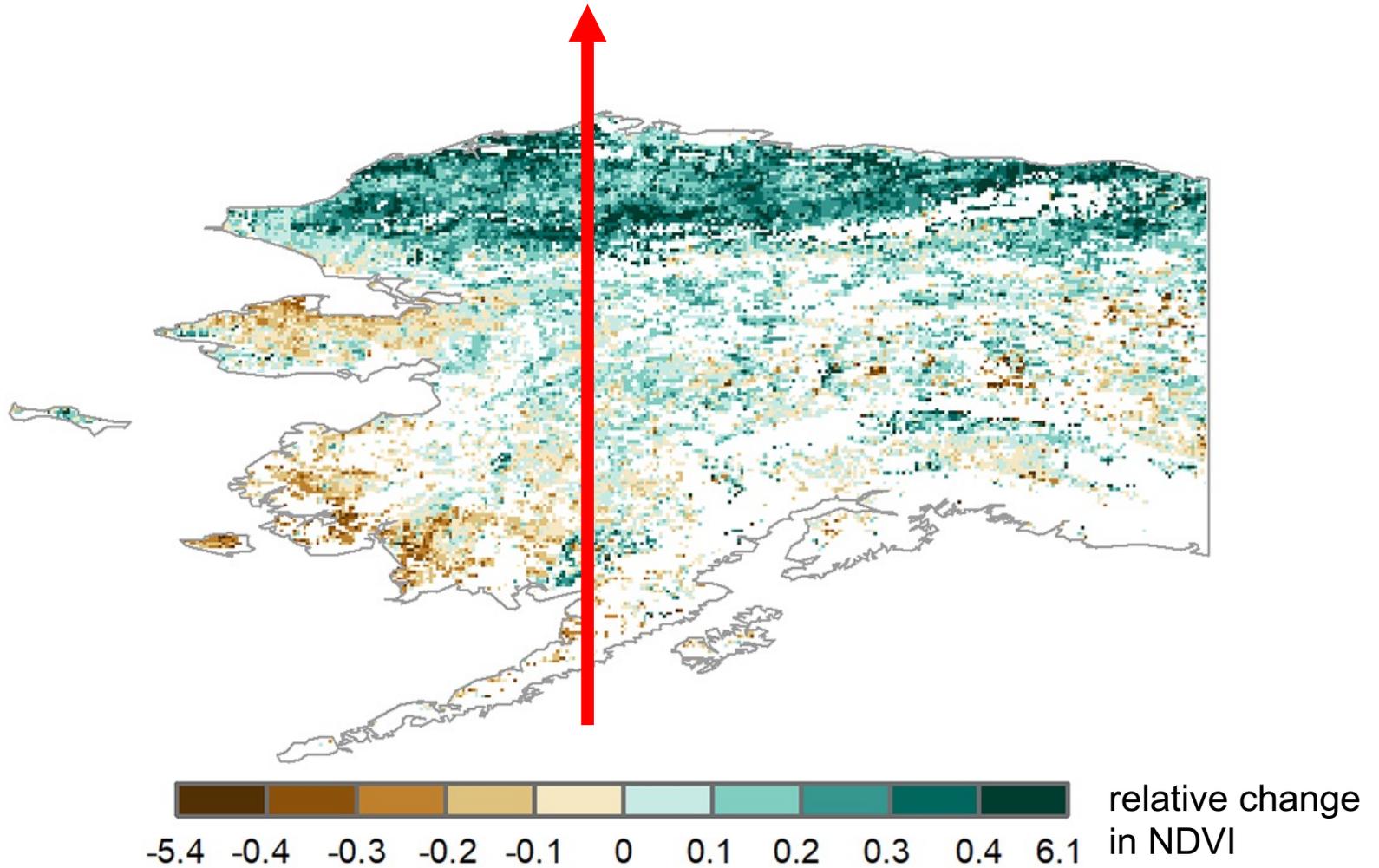
Mean greenness
(NDVI) 1982-2015



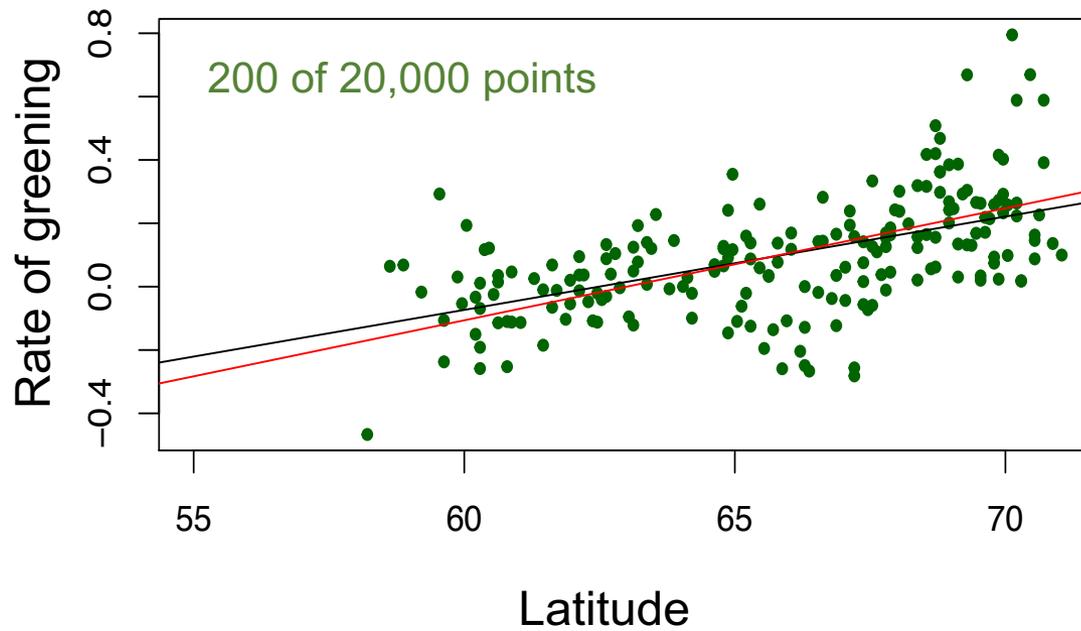
Change in
greenness (NDVI)
1982-2015



Does greening increase with latitude?



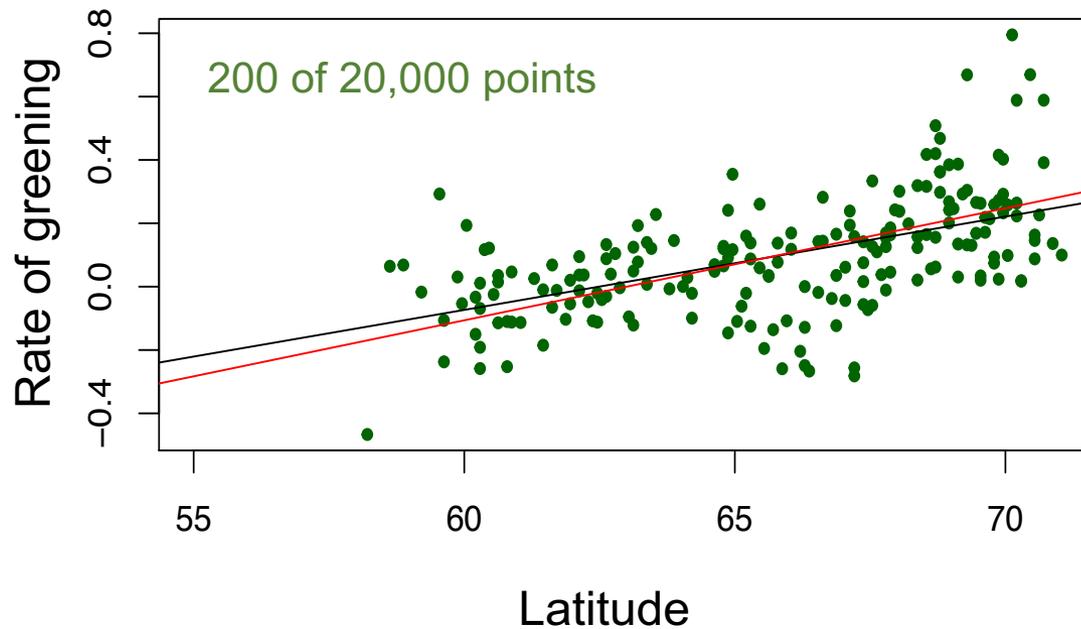
Does greening increase with latitude?



Regression
 $P < 10^{-15}$

Does greening increase with latitude?

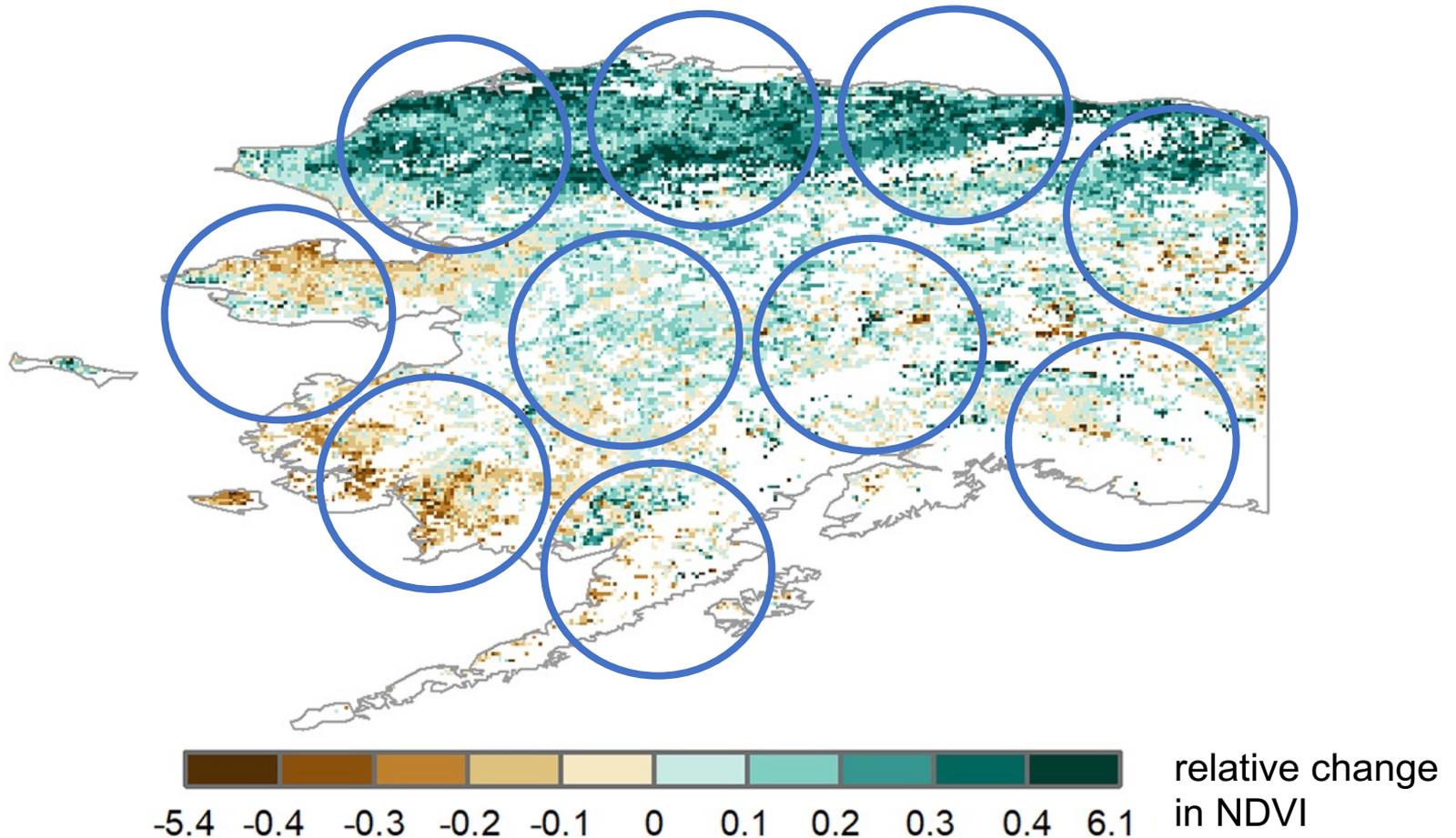
PARTS regression-like model
greening ~ *latitude* $P = 0.0013$



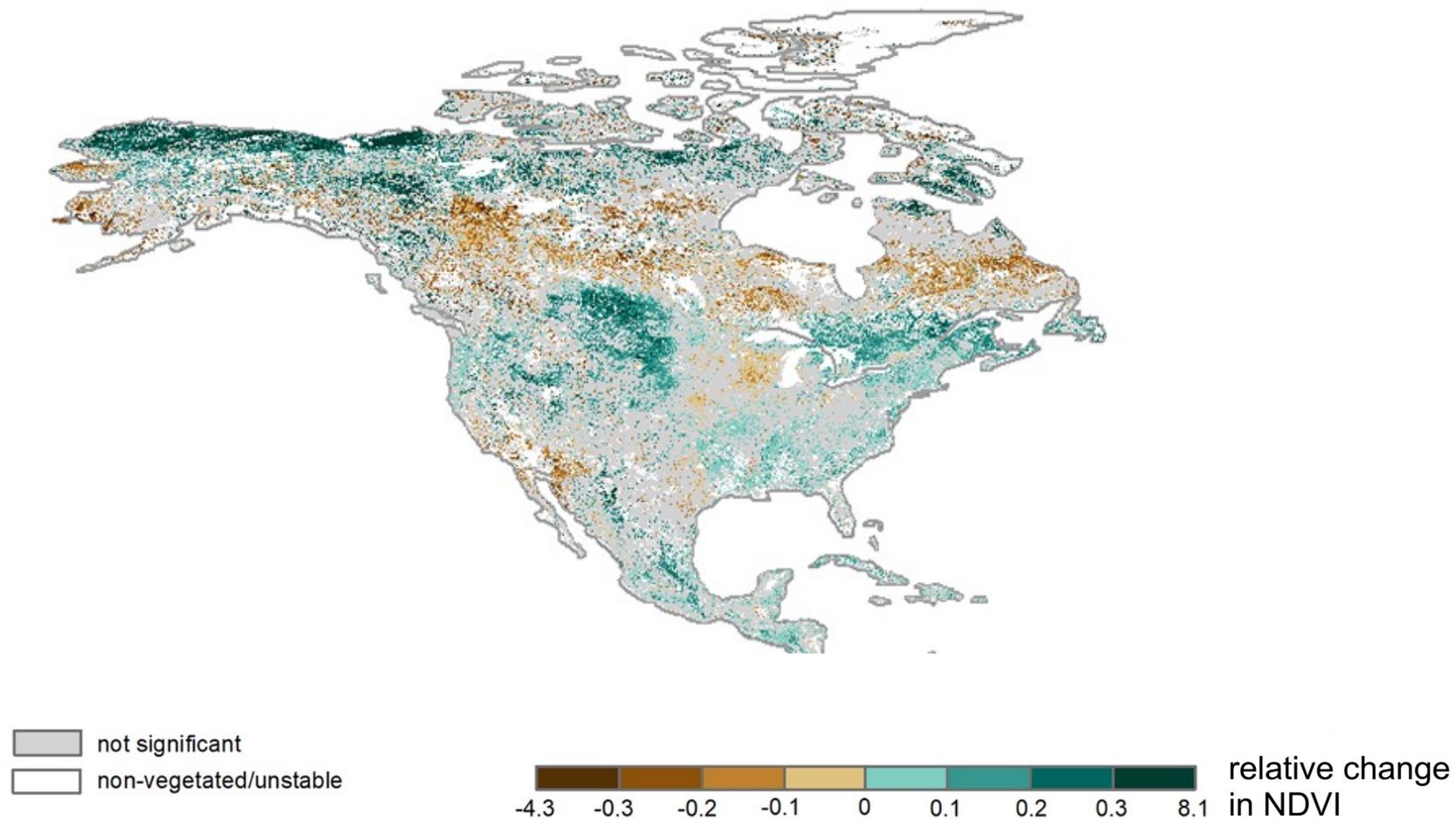
Regression
 $P < 10^{-15}$

Does greening increase with latitude?

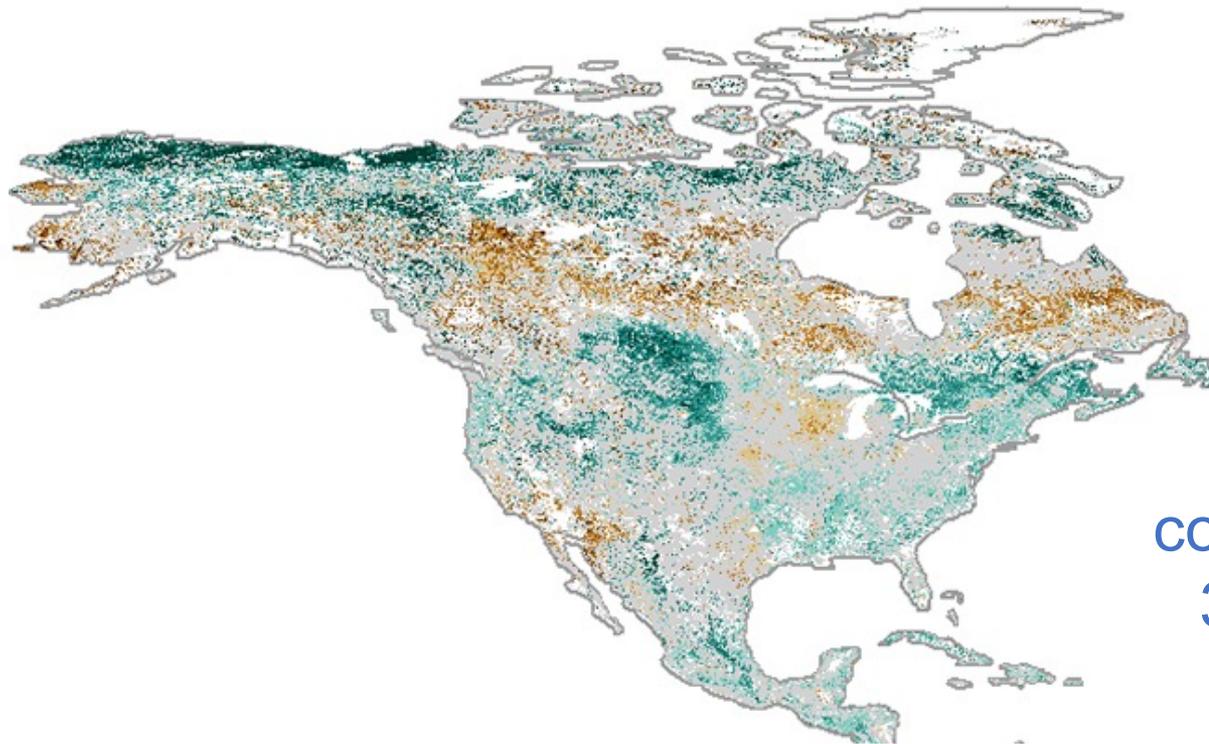
REALITY CHECK: There aren't many independent pieces of information



Does greening increase with latitude for North America?



Does greening increase with latitude for North America?



PARTS
 $P = 0.73$

computation time
345,264 pixels
6 min

not significant
non-vegetated/unstable

relative change
in NDVI

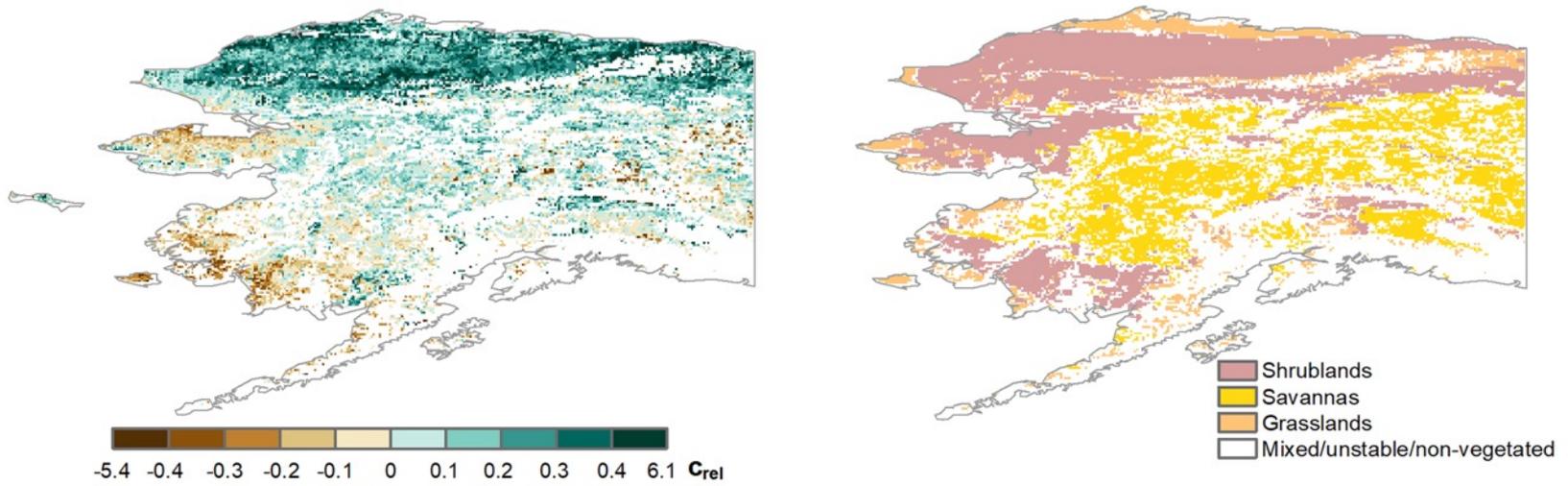
-4.3 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 8.1

PARTS results for continents

Differences in greening with latitude

Continent	<i>n</i>	<i>P</i>
Africa	214,121	0.44
Asia	570,250	1.00
Australia	91,459	0.61
Europe	174,498	0.08
North America	345,264	0.75
South America	190,832	0.15

Does greening differ among land-cover classes?



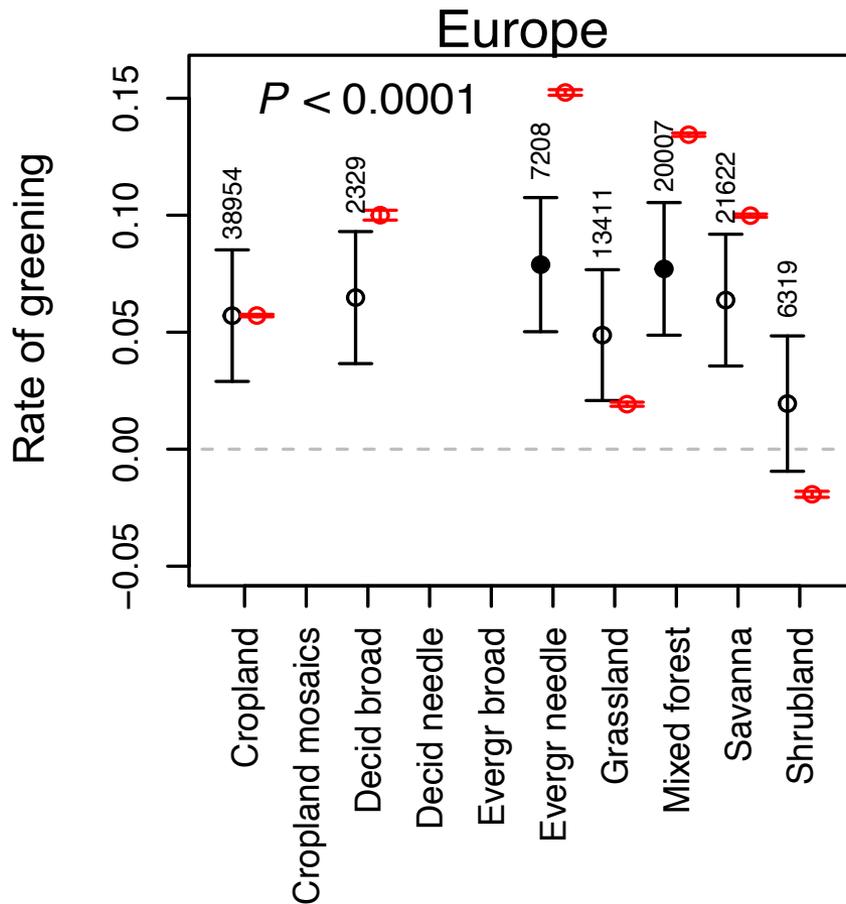
PARTS regression-like model
greening ~ land-cover class

$$P = 0.009$$

Savannas < Grasslands = Shrublands

PARTS results for continents

Differences in greening among land-cover classes



red = average trend (\pm se) per pixel

black = PARTS mean (\pm se for zero)

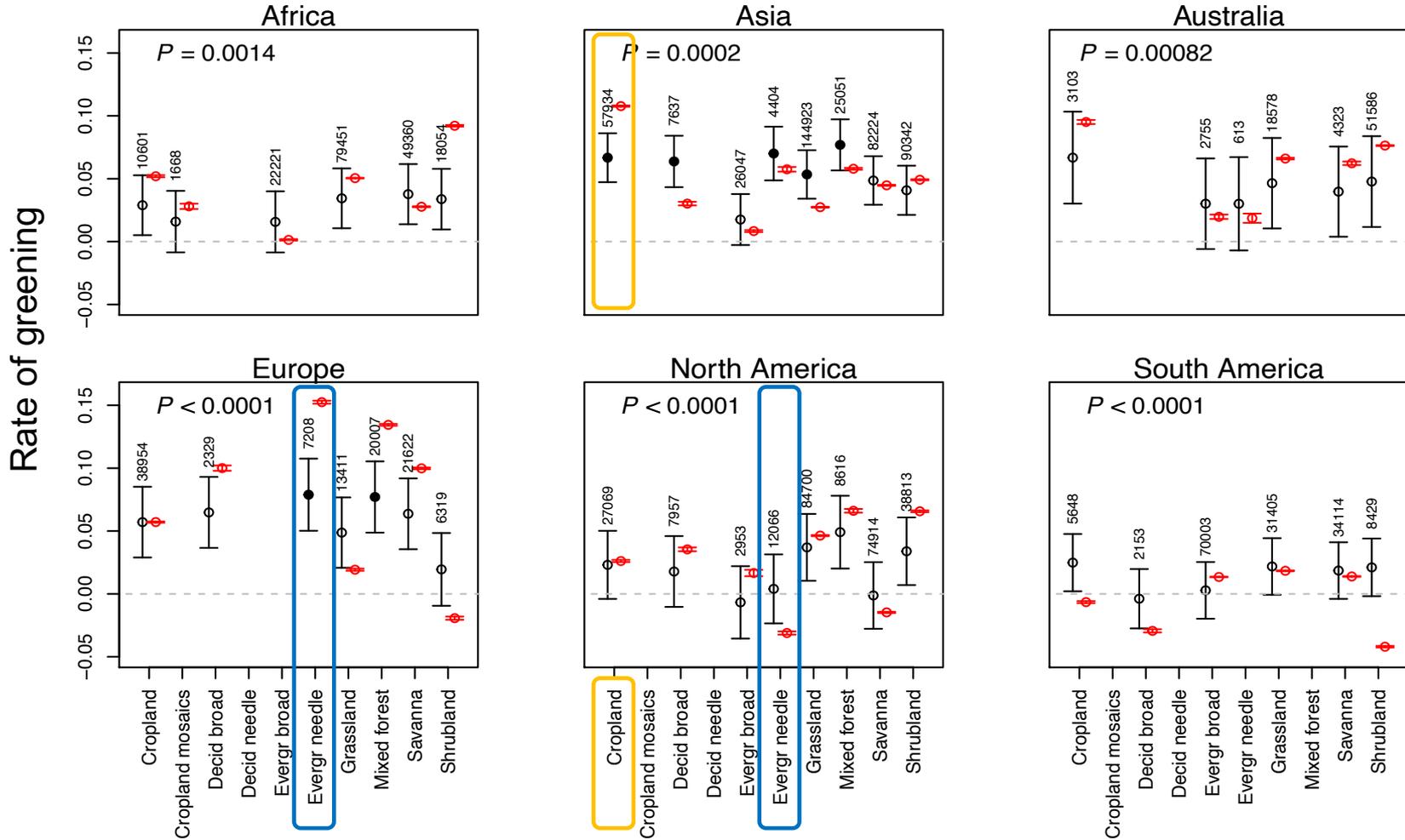
n = number of pixels

P for differences among land-cover classes

solid dot for differences from zero

PARTS results for continents

Differences in greening among land-cover classes



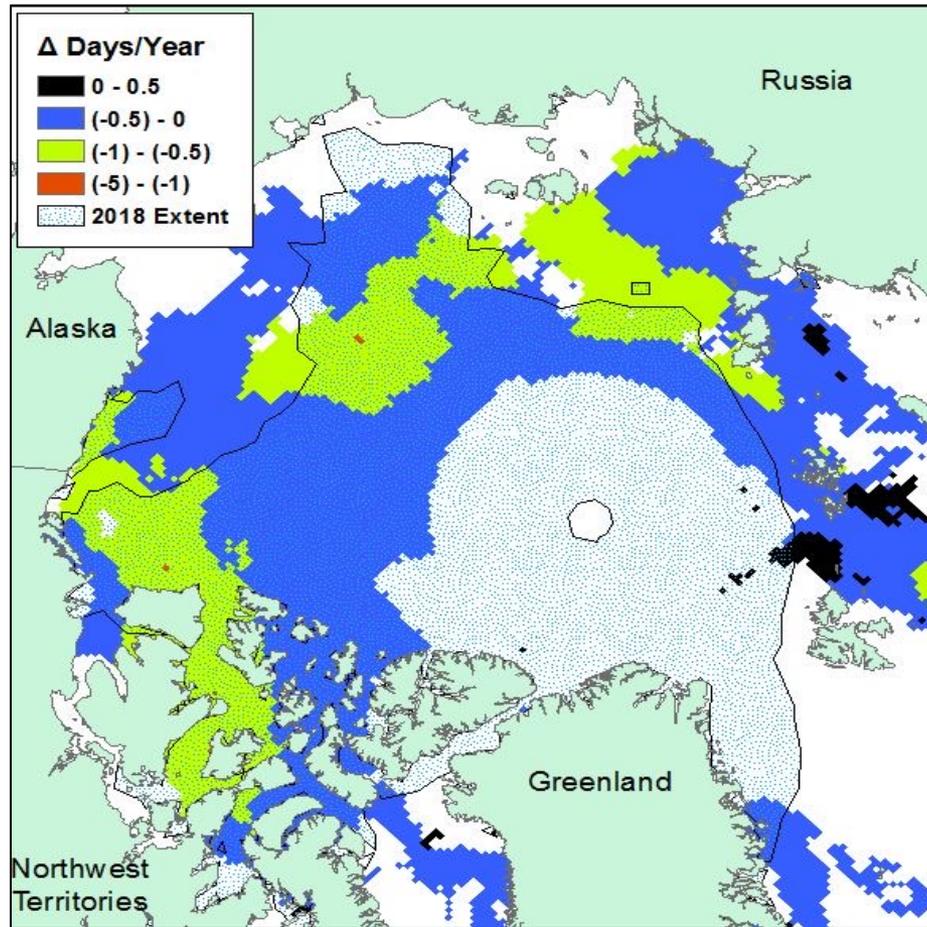
Summary

1. Greening is not uniform over the Earth
2. The patterns are not simple: they are not caused solely by global warming
3. Before trying to explain the patterns, it is first necessary to know whether there is statistical evidence that the patterns really exist

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Loss of days of ice cover in September

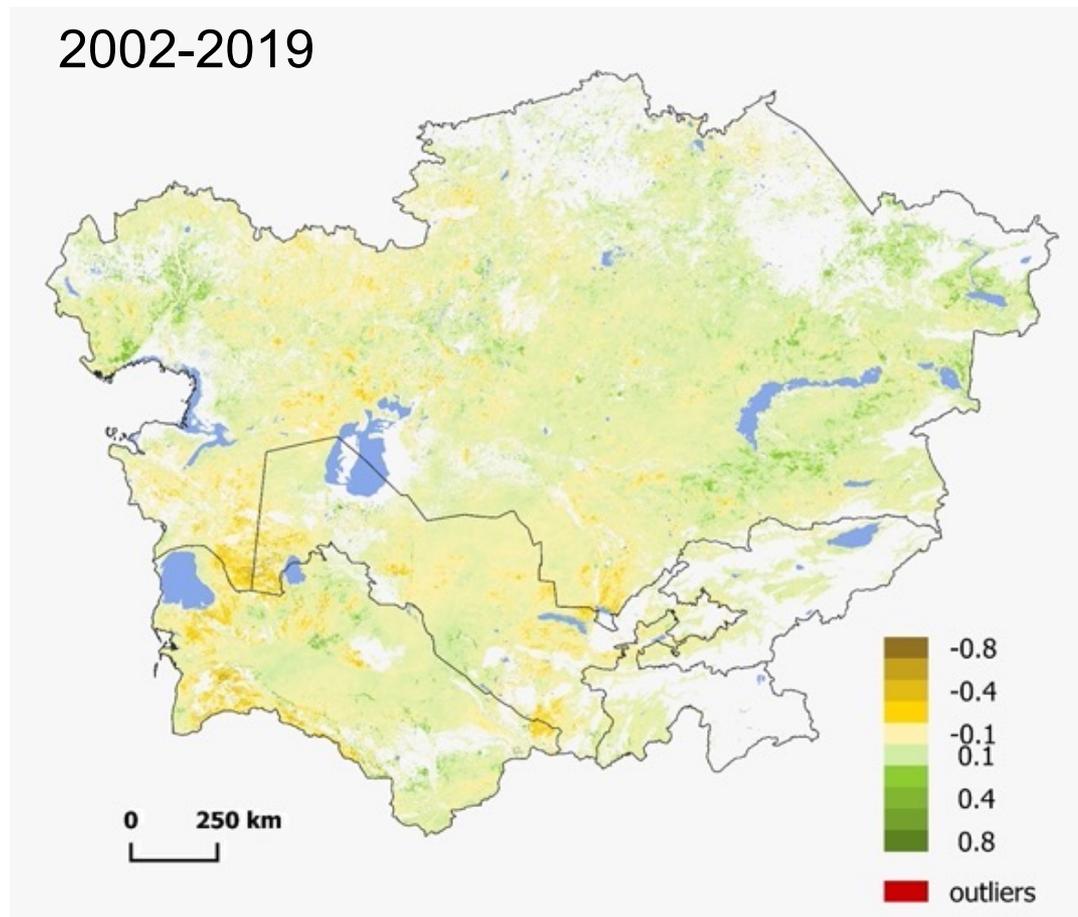


1979-2018

Connor Stephens

Change in rain-use efficiency in Central Asia

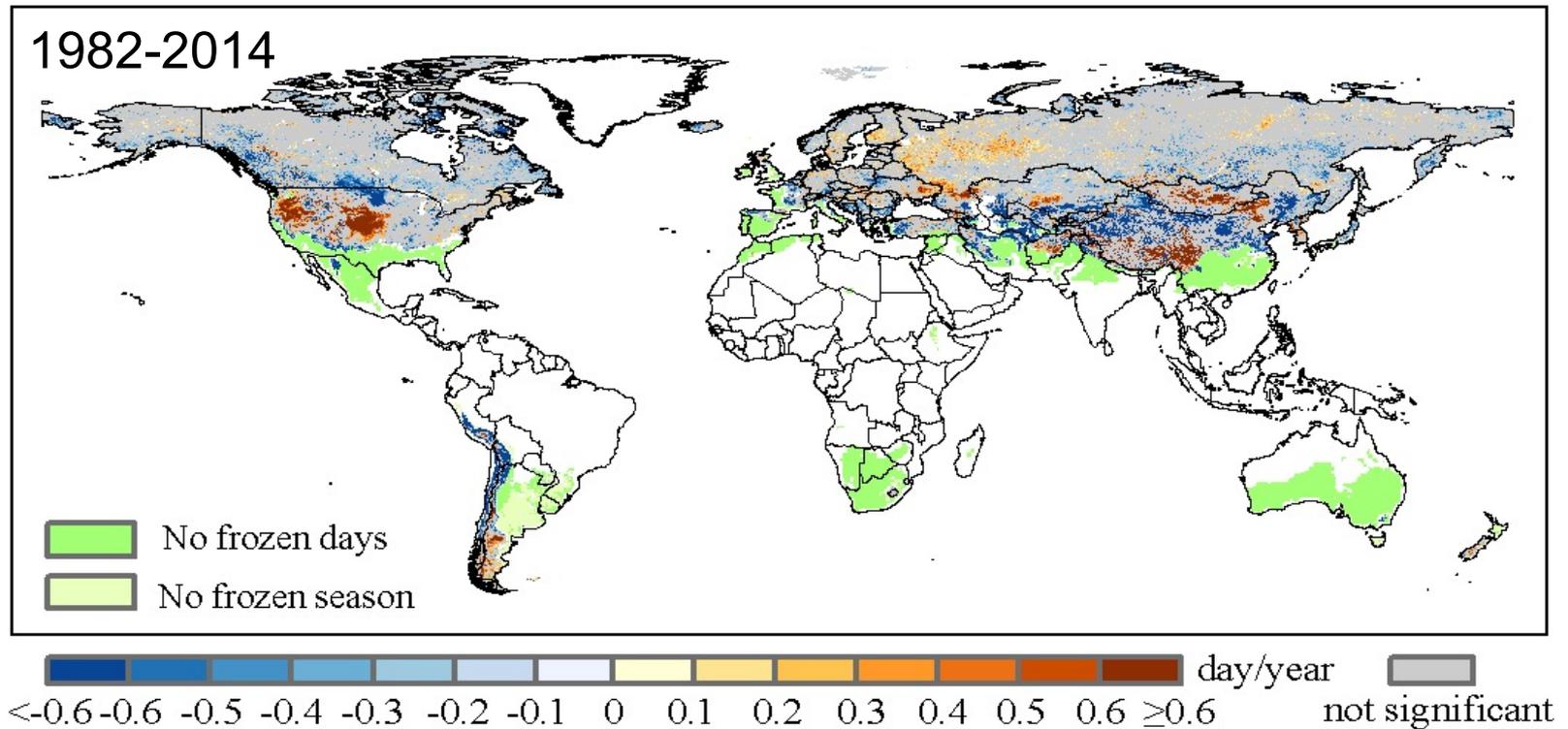
NDVI/precipitation indicates ecosystem functioning



Kasia Lewinska

Change in the number of days with frozen ground and no snow cover

Frozen ground with no snow is functionally colder



Likai Zhu

Take-homes

1. Statistics make the most of NASA's hard-won global data
PARTS tests global-scale hypotheses
2. Statistics give a reality check
PARTS isn't fooled by extraneous patterns
3. Statistics should be accessible and easy-to-use
R package `remotePARTS`
(search "Clay Morrow remotePARTS GitHub")
Please contact us if you have suggestions